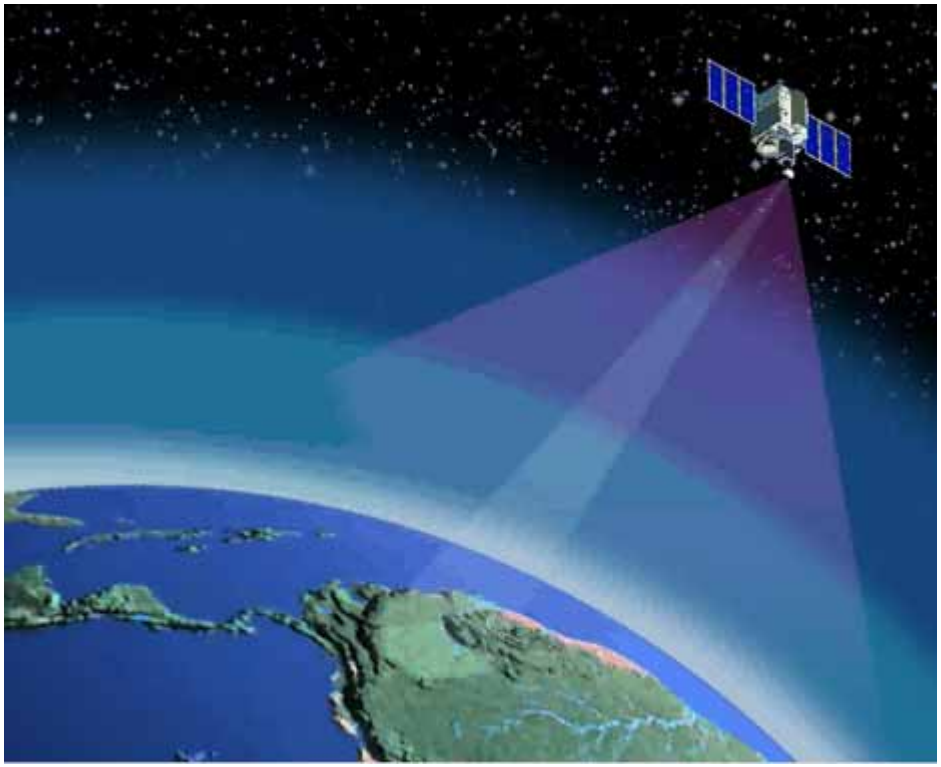
Advanced Satellite Aviation-weather Products

Advanced Satellite Aviation-weather Products



ASAP: An partnership between NASA and the FAA to infuse high-resolution satellite data into aviation weather products for ground and airborne users.

ASAP Partners

Advanced Satellite Aviation-weather Products

Primary Partners:

NASA Applied Sciences Program (Sponsor)

NASA Aviation Safety and Security Program (Sponsor)

FAA Aviation Weather Research Program

Government and University Laboratories

Major Affiliates:

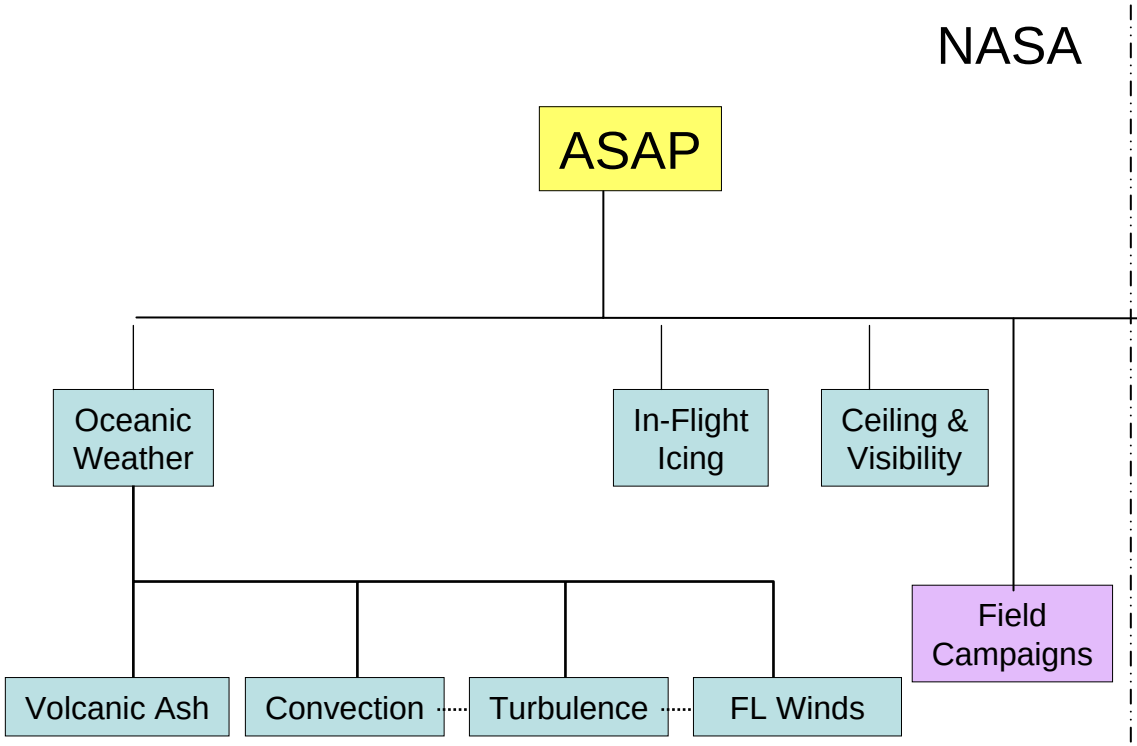
NASA/DOT/DOC/DOD/DHS Joint Planning and Development Office

OFCM

Aviation Industry

ASAP Project Structure

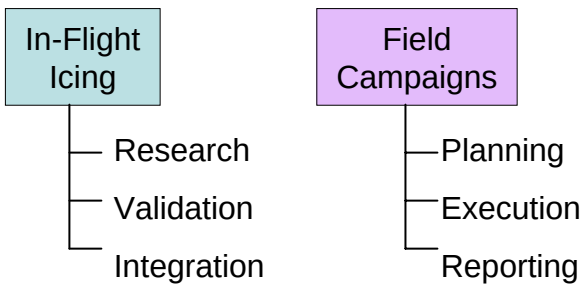
Advanced Satellite Aviation-weather Products



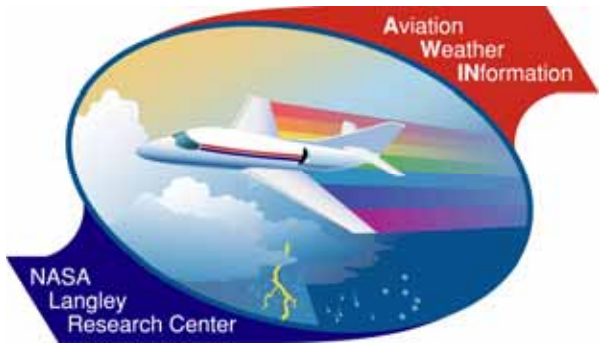
Aviation Weather Research Program Product Development Teams

- In-Flight Icing
- Convective Weather
- Turbulence
- Oceanic Weather
- National Ceiling and Visibility
- Terminal Ceiling and Visibility
- Winter Weather
- Model Development and Enhancement
- Aviation Forecasts
- Quality Assessments
- NEXRAD Algorithms

Typical Product Development Processes



ASAP In-flight Icing Achievements



Aviation Safety and Security Program
2004 Technical Accomplishment

NASA ASAP In-flight Icing Products

POCs: Patrick Minnis[1], John Murray[1], Louis Nguyen[1], Marcia Politovich[2] and Cory Wolff[2]

Relevant Milestone: To produce, refine, validate and deliver an operational real-time satellite Icing Risk product and associated real-time cloud microphysical products to the FAA Aviation Weather Research Program (AWRP) In-flight Icing Product Development Team for evaluation and integration into the operational NWS Current Icing Potential Product (CIP).

Shown: The ability to produce and provide access to real-time, satellite-based, in-flight icing interest fields over the CIP domain.

Accomplishment/Relation to Milestone: Successfully produce and provide a suite of four satellite products to the FAA AWRP In-flight Icing PDT: 1) satellite Icing Risk composite, 2) Cloud Phase, 3) Effective Cloud Height and 4) Effective Droplet Radius.

Benefits: Enhancement of the Current Icing Potential and Forecast Icing Potential Products by providing satellite discriminators especially in regions where radar, pilot reports and other observations are sparse or in need of reinforcement.

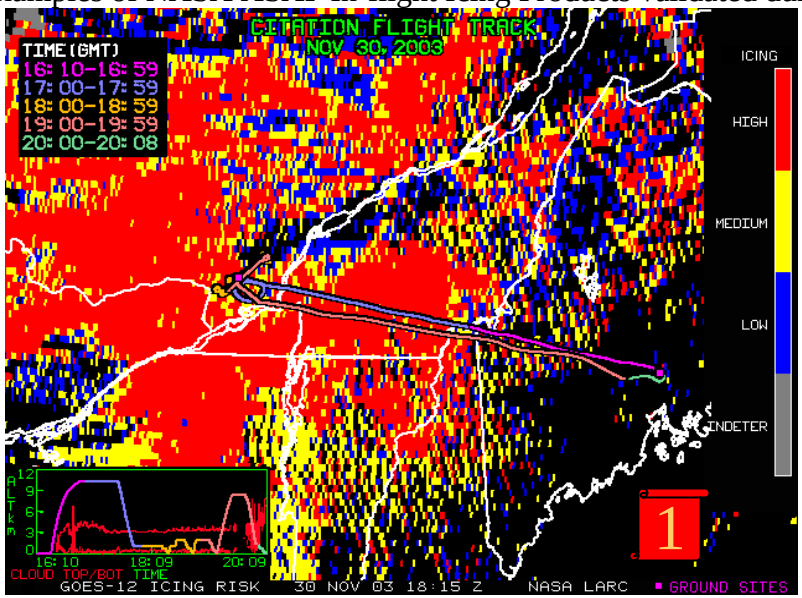
Plans: Continue validation and improvement of the satellite algorithms and begin integration of selected discriminators into the Current Icing Potential Product.

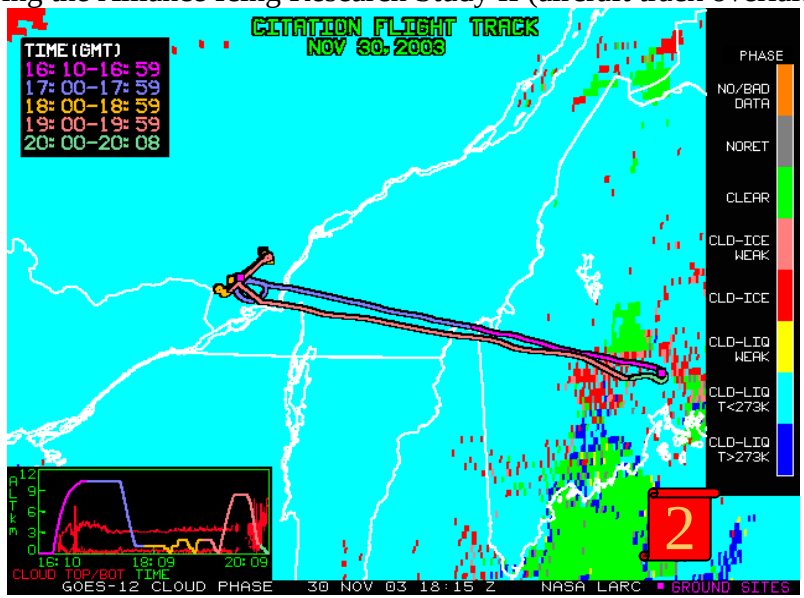
[1] NASA Langley Research Center
[2] National Center for Atmospheric Research

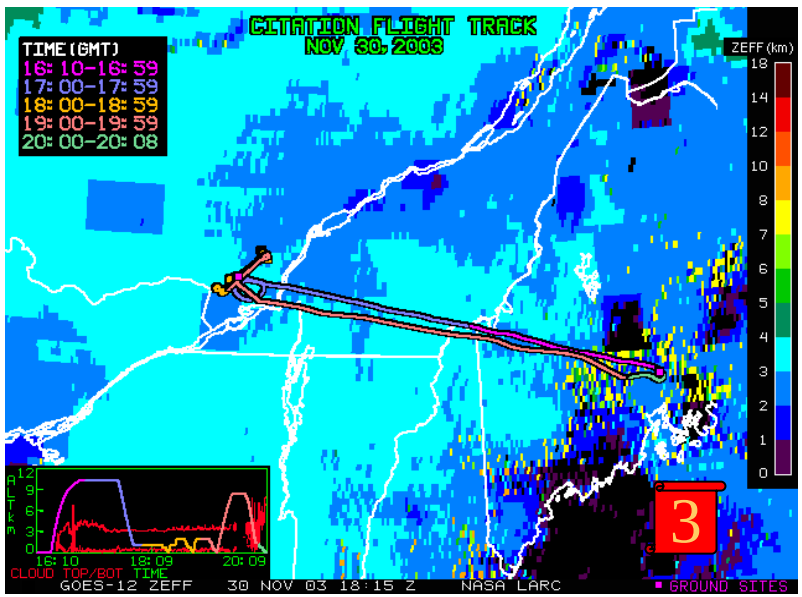
Aviation Safety and Security Program
2004 Technical Accomplishment

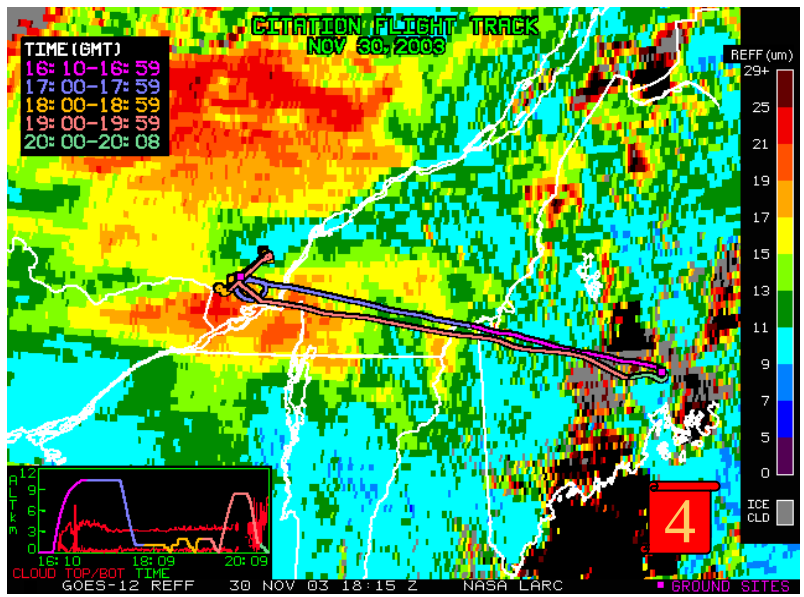
NASA ASAP
In-flight Icing Products

Examples of NASA ASAP In-flight Icing Products validated during the Alliance Icing Research Study II (aircraft track overlaid)









1 Icing Risk
2 Cloud Phase
3 Effective Z
4 Effective R

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2005 Technical Accomplishment

NASA ASAP In-flight Icing Products

POCs: Julie Haggerty[1], Patrick Minnis[2], John Murray[2], Marcia Politovich[1]

Relevant Milestone: To integrate NASA LaRC satellite-derived cloud microphysical products into the operational NWS Current Icing Potential (CIP) product developed by the FAA Aviation Weather Research Program (AWRP) In-flight Icing Product Development Team.

Shown: The ability to incorporate satellite-derived cloud phase and liquid water path into CIP algorithms to obtain improved estimates of the icing severity index.

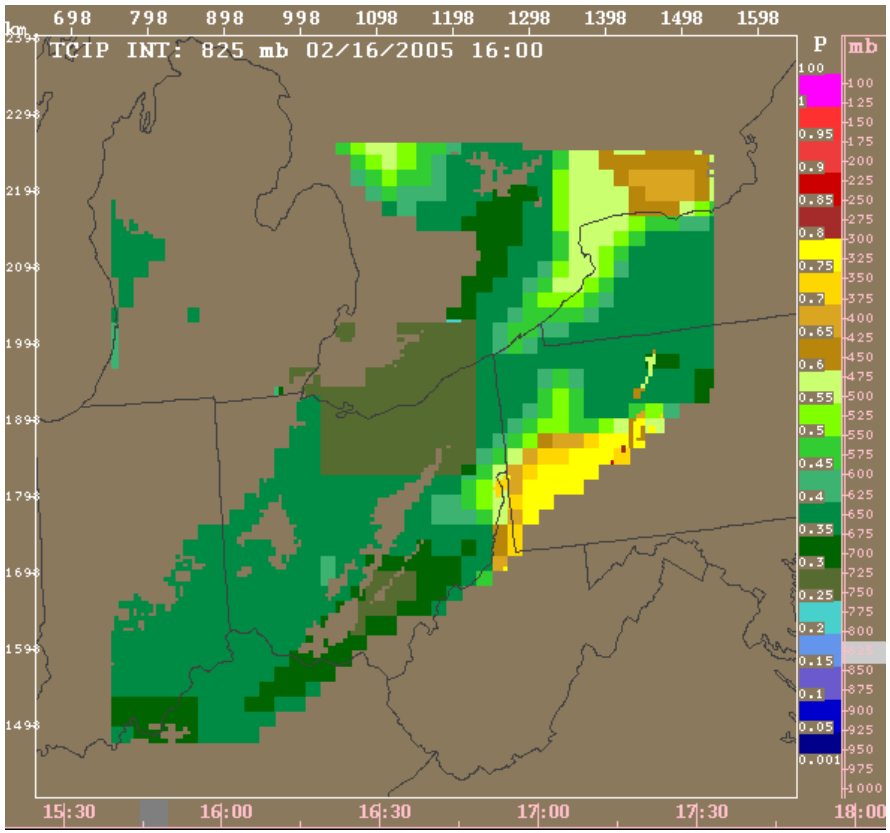
Accomplishment/Relation to Milestone: Successfully demonstrate the first use of advanced satellite cloud products as interest fields in CIP.

Benefits: Enhancement of the CIP severity product by exploiting satellite discriminators to improve detection of liquid phase cloud tops, estimates of cloud liquid water content, and spatial resolution of severity product.

Plans: Refine integration methods and explore use of additional satellite products in CIP. Continue analysis of case studies that combine satellite products with existing CIP data sources.

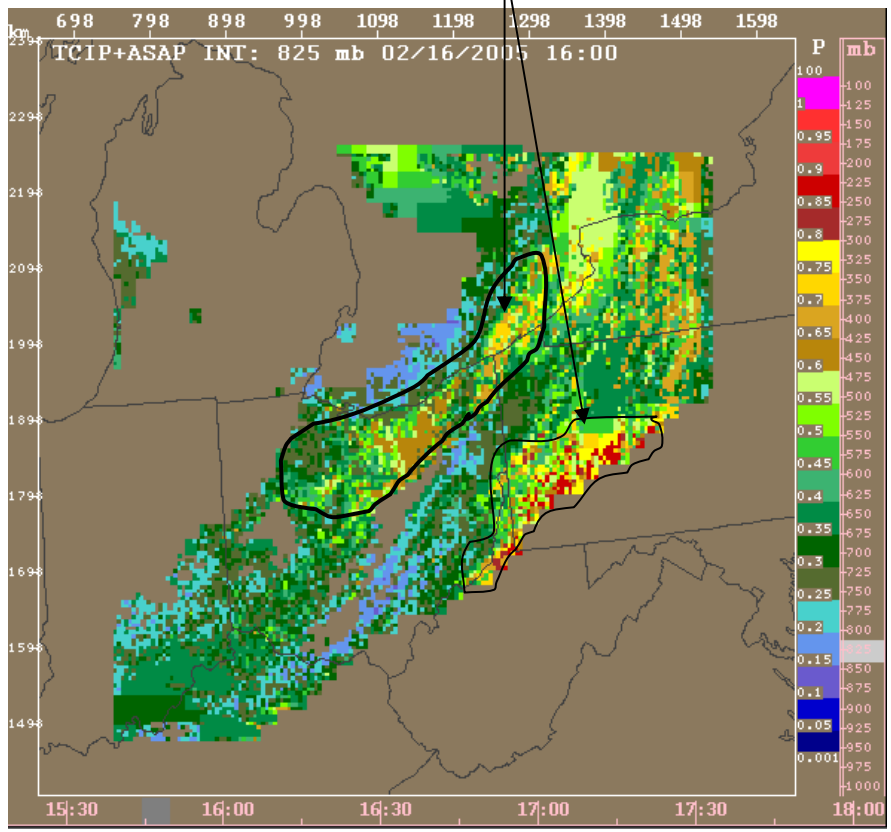
[1] *National Center for Atmospheric Research*
[2] *NASA Langley Research Center*

Current Icing Potential (CIP) Icing Severity Index on 16 February 2005



Original estimate at 825 mb. Severity index increases from bottom to top of scale. Areas outside the colored pixels have negligible icing potential at this level.

Areas of high LWP



Modified by inclusion of satellite-derived phase and liquid water path products. Note improved spatial resolution and increased values of severity index corresponding to high LWP.

Aviation Safety and Security Program
2005 Technical Accomplishment

Transition of NASA ASAP In-flight Icing Products to Project Columbia Supercomputer

POCs: Louis Nguyen[1], Rabindra Palikonda[2], Patrick Minnis[1], and John Murray[1]

Relevant Milestone: To migrate the NASA ASAP In-flight Icing system to Columbia for the transition and integration of icing fields (cloud phase, liquid and ice water path, cloud height and temp, particle size, etc) to the operational NWS Aviation Weather Center Current Icing Potential Product (CIP).

Shown: Major components of the In-flight Icing system ported to Project Columbia supercomputer which provides an optimal platform and the ability to produce and deliver icing interest fields at improved speeds.

Accomplishment/Relation to Milestone: Successfully migrated, compiled, and tested one component of the In-flight Icing system: the McIDAS real-time data acquisition sub-system. Communication protocol established and provides reliable real-time input data from two independent sources. Migrated several key In-flight Icing satellite processing modules.

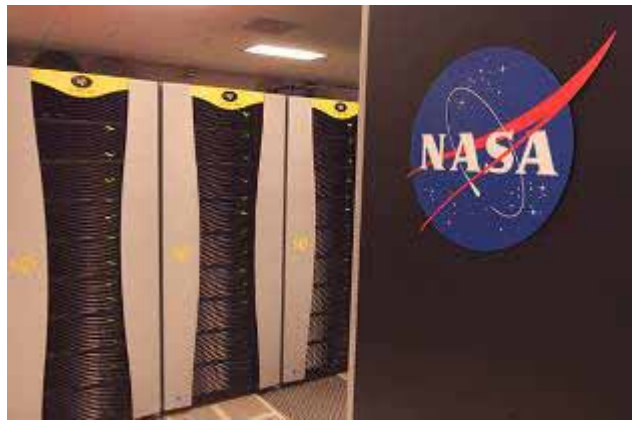
[1] *NASA Langley Research Center*
[2] *Analytical Services and Materials, Inc.*

Aviation Safety and Security Program
2005 Technical Accomplishment

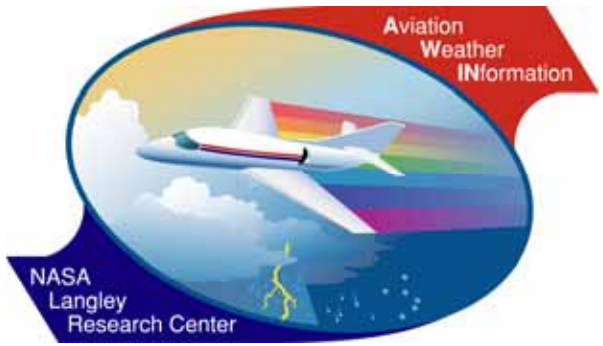
Project Columbia Supercomputer Transition of NASA ASAP In-flight Icing Products

Benefits: Improvement of In-flight Icing processing system by utilizing multi-processors to deliver icing fields to Current Icing Potential at higher temporal and spatial resolution with reduced latency time.

Plans: Continue migration and validation of NASA In-flight Icing system on Project Columbia and to adapt and improve satellite cloud algorithms to run in parallel processing mode.



ASAP Convective Weather Achievements



Aviation Safety and Security Program
2005 Technical Accomplishment

NASA ASAP Convective Initiation Satellite Products

POCs: John Mecikalski[1], Kristopher Bedka[2], Todd Berendes[1], and Simon Paech[1]

Relevant Milestone: To produce, refine, validate and deliver an operational real-time satellite 0-1 hour Convective Initiation (CI) forecast product that may be used to improve airport efficiency and thunderstorm warnings/avoidance. Demonstrate CI products within FAA AWRP systems as new satellite interest fields bolster current radar-based algorithms.

Shown: The ability to produce and provide access to real-time, satellite-based, CI interest fields over any region covered by GOES imagery. This includes the Dallas-Fort Worth (DFW) demonstration domain and the Northeast corridor, as done in summer 2005.

Accomplishment/Relation to Milestone: Successfully produce and provide a suite of eight satellite "interest fields" to the FAA AWRP Convective Weather PDT for testing an evaluation. Developed new methods to test forecast skill and confidence on the 1 km scale. Transfer to Convective Weather PDT.

Benefits: Enhancement of the AutoNowcaster system over the DFW and Northeastern U.S. regions. Provide critical 30 min-1 hour lead time to first radar echo using GOES. Airport delay mitigation.

Plans: Continue validation and improvement of the satellite algorithms and begin integration of selected discriminators into the AutoNowcaster and Tactical Convective Weather Forecast (TCWF) and National Convective Weather Forecast (NCWF) systems.

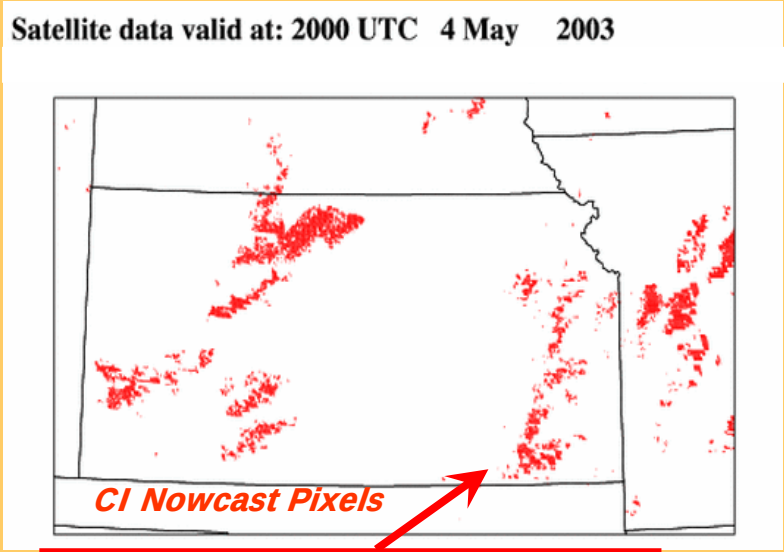
[1] *University of Alabama in Huntsville, Atmospheric Science Department*
[2] *Cooperative Institute for Meteorological Satellite Studies, University of Wisconsin--Madison*

Aviation Safety and Security Program
2005 Technical Accomplishment

NASA ASAP Convective Initiation Products

Examples of NASA ASAP Convective Initiation Products implemented in AutoNowcaster; ***False alarms reduced***.

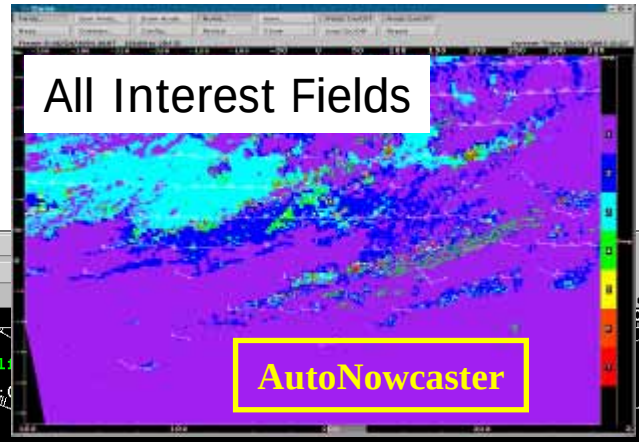
ASAP Satellite CI Product

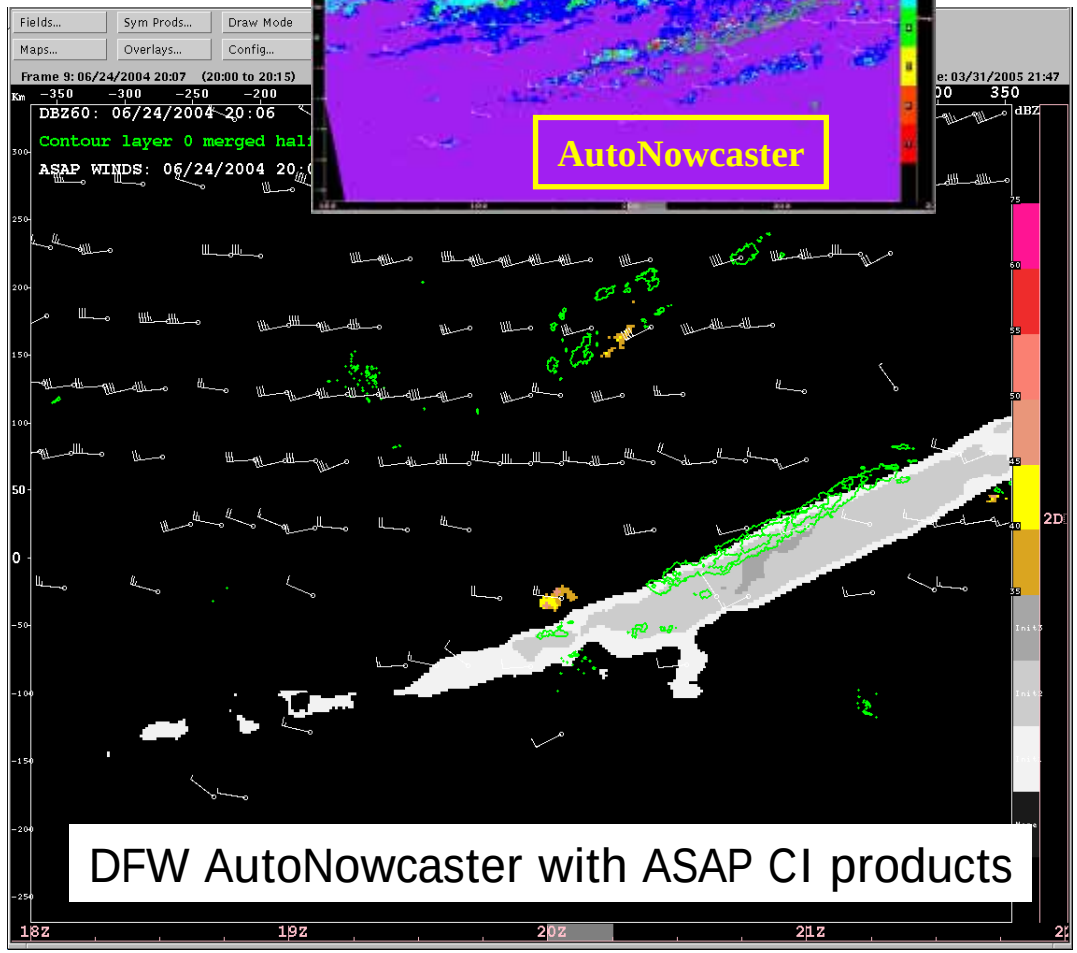


Red Pixels are forecasted CI locations in next 60 min

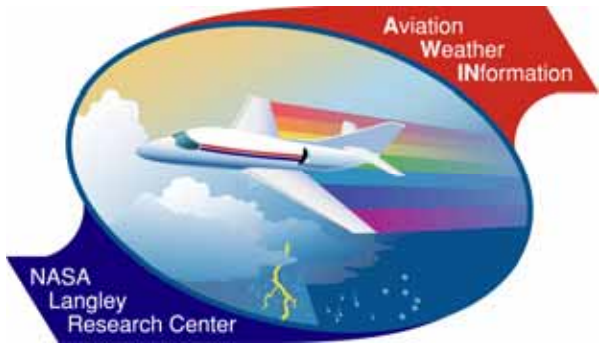
- Satellite-based CI indicators provided *30-60 min advanced notice* of CI in north, and eastern Kansas

Transition





ASAP Volcanic Ash Detection Achievements



Aviation Safety and Security Program
2004 Technical Accomplishment

Evaluation of DOD Satellite Data for Volcanic Eruption Detection and Ash Cloud Monitoring

POCs: Earle Williams, MIT Lincoln Laboratory
John Murray, NASA Langley Research Center

Relevant Milestone: This study demonstrates the feasibility of using DOD monitoring Satellites date to detect heat signatures of volcanic eruptions and ash clouds.

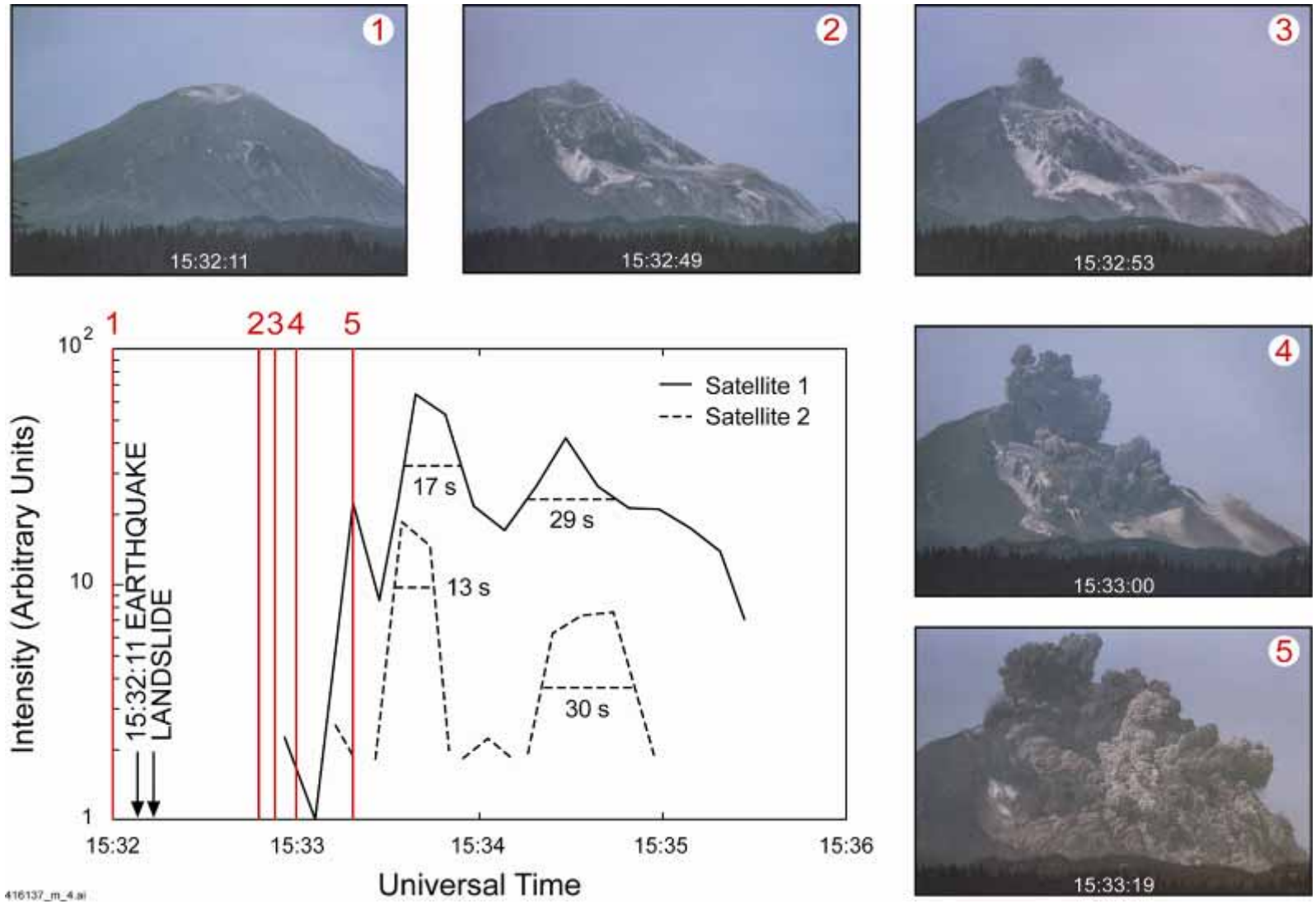
Shown: DOD satellites provide the only global capability to provide a 5-minute warnings of volcanic eruptions but the signal can be attenuated by atmospheric water vapor.

Accomplishment/Relation to Milestone: This study has also has demonstrated the connection between quantitative DoD satellite observations and the traditional volcanological assignment of eruption hazard—the Volcanic Explosivity Index (VEI). This connection is particularly important to aviation because the VEI assignment is used to estimate plume height.

Benefits: A recurrent message at the recent Conference on Volcanic Ash and Aviation Safety was that there is a need for a 5-minute warning on volcanic eruptions. The addition of DOD Satellite Data can significantly decrease eruption warning time and provide spatial characterization of the ash cloud.

Plans: A larger number of eruption records are needed to establish better relationships between satellite radiance signatures (peak intensity, half widths) and the volcanological parameters (Volcanic Explosivity Index, eruption energy, ash plume height) relevant to the aviation hazard of volcanic ash. This follow on work has been undertaken for completion in 2005.

Volcanic Eruption Detection and Ash Cloud Monitoring



Initial Stage of Mt St Helens from the Ground and from DoD Satellites in Space

Aviation Safety and Security Program
2005 Technical Accomplishment

NASA ASAP Volcanic Ash CLAVR-X

POCs: Wayne Feltz[1], Michael Pavolonis[1], Steve Ackerman[1], and Michael Richards[1]

Relevant Milestone: Develop automated volcanic ash detect and height estimate methodology which works universally on operational polar (AVHRR,MODIS) and geostationary (GOES) radiance data.

Shown: An automated volcanic ash and height detection methodology which limits false detection and capably works during daytime at all latitudes for mid and high level ash plumes.

Accomplishment/Relation to Milestone: UW-CIMSS Volcanic ash detection methodology improves well known reverse absorption technique by limiting false alarms and providing more ash cloud detail than available in past. Volcanic cloud ash height estimate is now available which can be used to drive trajectory model nowcasting at Volcanic Ash Advisory Centers (VAACs).

Pavolonis, M.J., W.F. Feltz, A.K. Heidinger, and G.M. Gallina, 2005: A daytime compliment to the reverse absorption technique for improved automated detection of volcanic ash. Submitted to JTECH

Benefits: Formal request for volcanic ash product has been submitted by Washington DC VAAC to NOAA so implementation of updated CLAVR-X code allowing ash detection is formally documented and delivered. The work has also been presented to FAA Ocean Weather PDT and will provide another resource as a FAA volcanic ash detection tool especially at high latitudes.

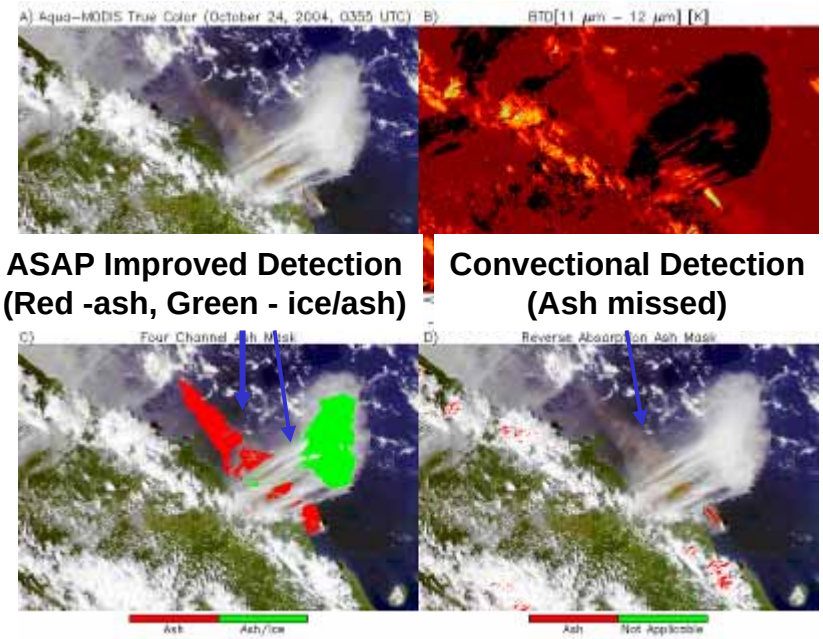
Plans: Continue validation and evaluation of methodology using polar (for high latitude) and geostationary satellite platforms. Implement methodology with GOES NOAA operational data stream. Provide optimized ash detection for MODIS imager and upcoming VIIRS sensor.

[1] *Cooperative Institute for Meteorological Satellite Studies, University of Wisconsin--Madison*

Aviation Safety and Security Program
2005 Technical Accomplishment

Volcanic Ash Detection and Height Estimates

From: FAA Aviation Safety Journal Vol. 2 (3)



ASAP Improved Detection (Red -ash, Green - ice/ash)

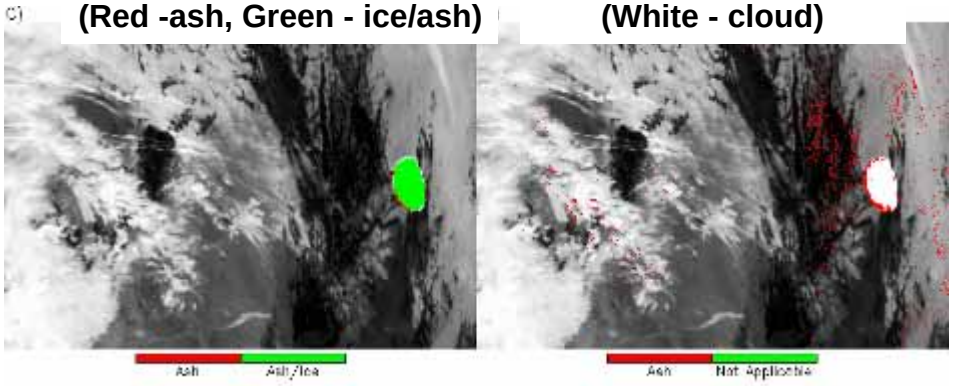
Convectional Detection (Ash missed)

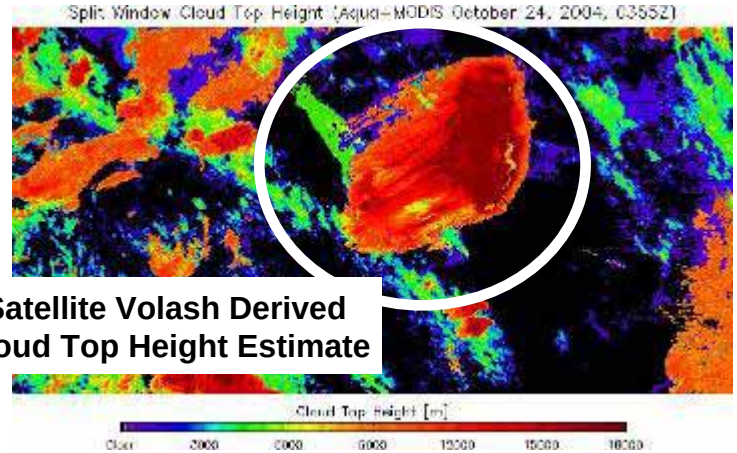
Mt Spur volcanic eruption detected from NOAA-11 on 19 August 1992 indicating improved detection (implemented in research mode in NOAA CLAVR-X datastream) compared to conventional reverse absorption methodology

Mt Manam volcanic eruption detected from MODIS on 24 October 2004 in more difficult tropical environment (above).

ASAP Improved Detection (Red -ash, Green - ice/ash)

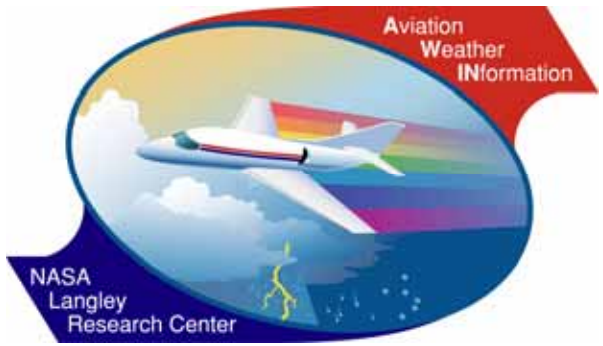
Convectional Detection (White - cloud)





Satellite Volash Derived Cloud Top Height Estimate

ASAP Turbulence Achievements



Aviation Safety and Security Program
2005 Technical Accomplishment

NASA ASAP Tropopause Turbulence Interest Fields

POCs: Wayne Feltz[1] and Anthony Wimmers[1]

Relevant Milestone: Develop and validate GOES and Rapid Update Cycle (RUC) derived upper tropospheric turbulence fold interest fields for incorporation into GTG to improve forecasting of clear air turbulence near satellite detected folds.

Shown: An automated GOES imager derived upper tropospheric fold product useful for locating regions of possible clear air turbulence.

Accomplishment/Relation to Milestone: The ASAP UW-CIMSS upper tropospheric fold product has been improved and validated with PIREP and aircraft reports. This information will be provide to NOAA Forecast System Laboratory (Dr. Steve Koch) to provide an additional interest field to the RUC model for detection of upper level turbulence. http://cimss.ssec.wisc.edu/asap/exper/tfoldsVer2/pirepSep.html

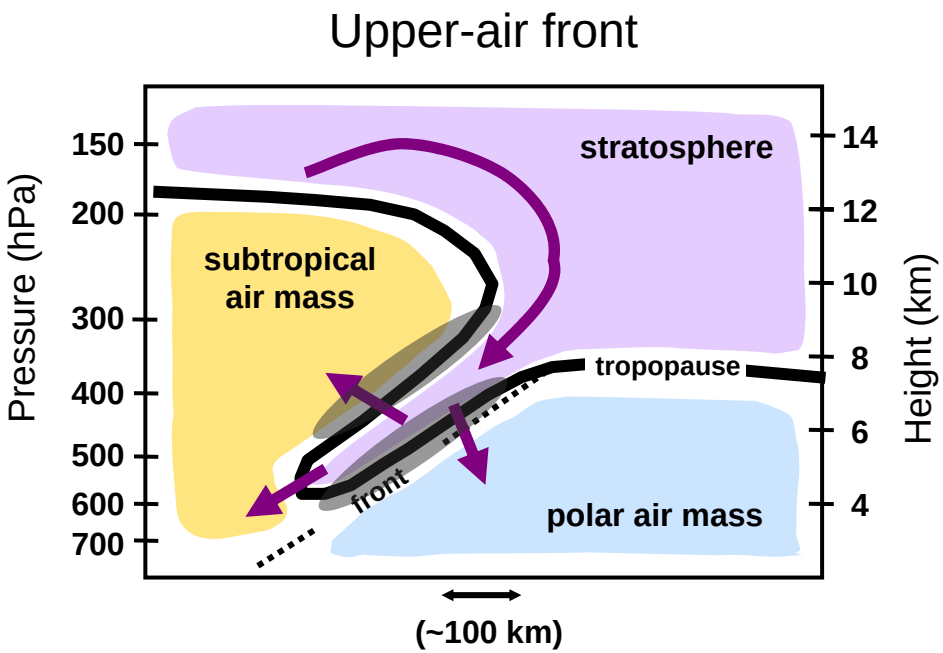
Benefits: The satellite derived tropopause fold product and GOES ozone gradient products will provide locations of interest to improve RUC Graphical Turbulence Guidance (GTG) clear air turbulence products via NOAA FSL and the FAA Turbulence PDT (Dr. Robert Sharman).

Plans: Continue validation of upper tropospheric fold product and incorporate satellite derived ozone gradients from GOES and NASA OMI sensor to apply confidence flag on satellite derived turbulence interest field.

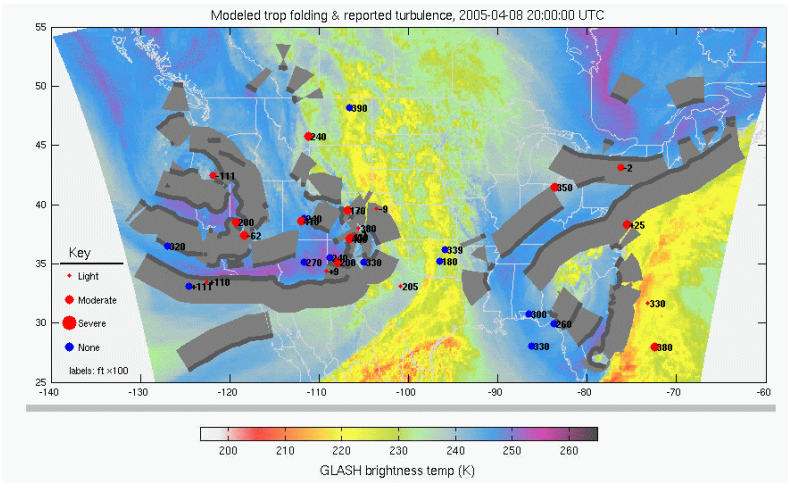
[1] *Cooperative Institute for Meteorological Satellite Studies, University of Wisconsin--Madison*

Aviation Safety and Security Program
2005 Technical Accomplishment

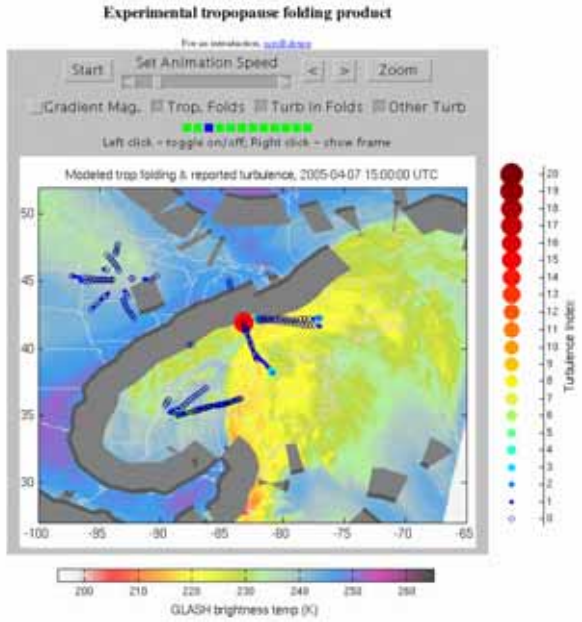
Upper Tropospheric Fold Turbulence Detection



This near real-time satellite product that estimates areas of tropopause folding in regions of strong humidity gradients in the GOES midwave infrared (water vapor) channel. Using an empirical relationship between upper tropospheric humidity gradients and tropopause breaks, the algorithm estimates that turbulence-generating tropopause folds protrude from some of these tropopause breaks. This product is validated over the United States with manual pilot reports as well as newer automated aircraft reports of turbulence.



Web product: Real-time pirep validation



Web product: Real-time TAMDAR validation

Aviation Safety and Security Program
2005 Technical Accomplishment

NASA ASAP Gravity/Mountain Wave Turbulence & Cloud Mask

POCs: John Mecikalski[1], Nathan Uhlenbrock[2], Todd Berendes[1], Wayne Feltz[2], and Kristopher Bedka[2]

Relevant Milestone: To produce, refine and deliver an real-time satellite products that describe; 1) cumulus cloud location for forecasting thunderstorm growth, 2) deducing convectively-induced turbulence (CIT) and 3) characterizing mountain waves which produce “moderate” to “severe” turbulence for commercial aircraft.

Shown: The ability to produce and provide access to real-time, satellite-based mountain wave and convective-induced turbulence signatures in GOES and/or MODIS 1 km-resolution imagery.

Accomplishment/Relation to Milestone: Successfully correlate satellite-identified mountain wave signatures with actual aircraft turbulence reports. Develop a “over-shooting cumulonimbus” component to the convective cloud mask that delineates upper-tropospheric gravity-wave generation zones.

Benefits: Eventual enhancement of NCAR’s GTG (Graphical Turbulence Guidance) clear-air turbulence (CAT) forecasting system, sponsored by the FAA Aviation Weather Research Program (AWRP), which NOAA currently runs operationally at the Aviation Weather Center (AWC).

Plans: Continue validation and improvement of the satellite algorithms and begin integration of selected discriminators into the GTG. Validation of other new satellite-based CIT identification products.

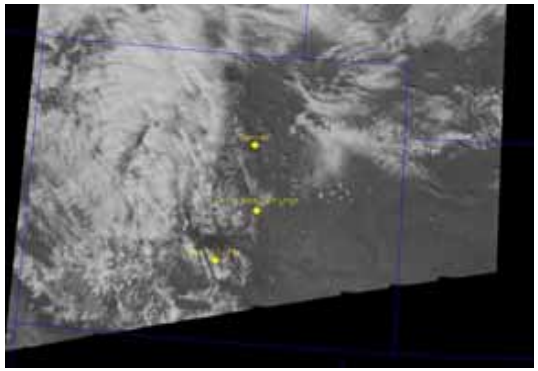
[1] *University of Alabama in Huntsville, Atmospheric Science Department*
[2] *Cooperative Institute for Meteorological Satellite Studies, University of Wisconsin--Madison*

Aviation Safety and Security Program
2005 Technical Accomplishment

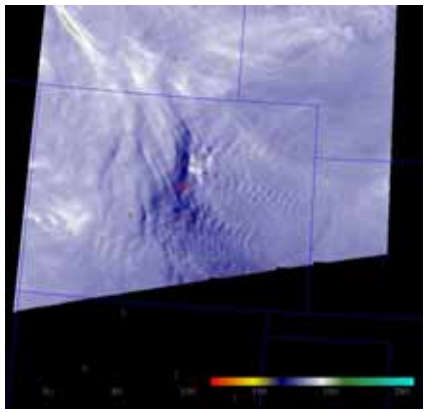
Wave Turbulence and Cloud Mask

Examples of NASA ASAP CIT and Mountain Wave Identification Algorithms to be tested and implemented in the GTG.

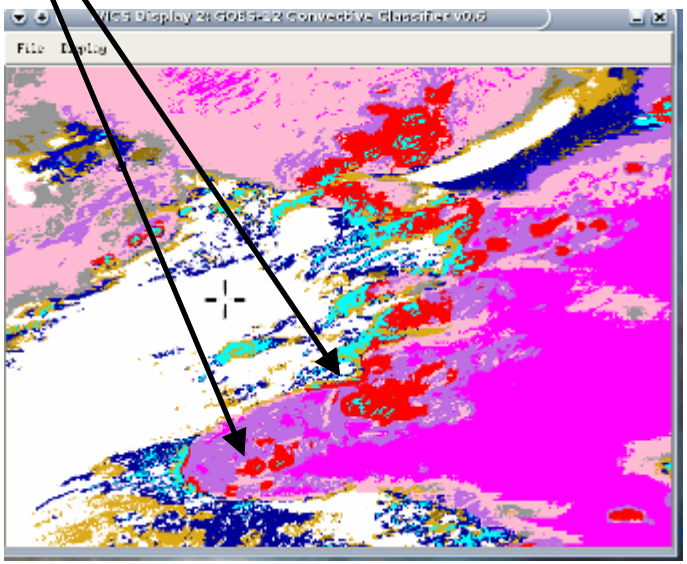
MODIS Visible Image over Colorado Front Range

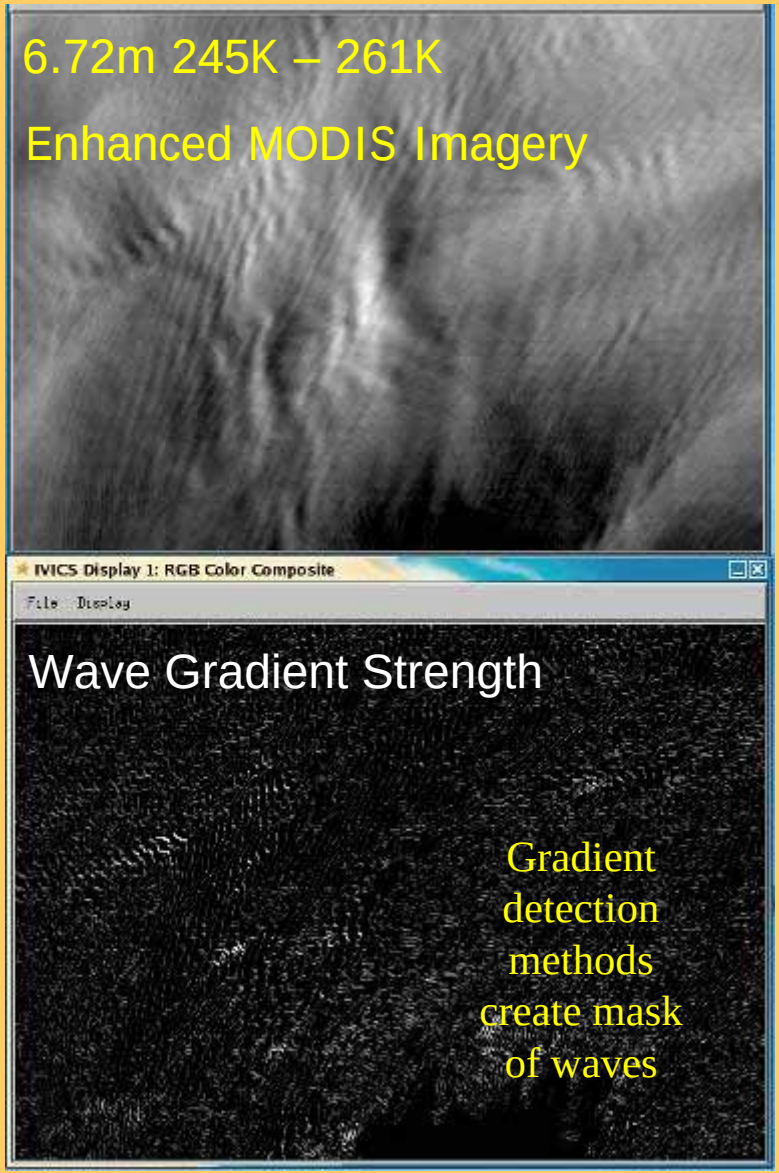


MODIS Water Vapor Image With Turbulence Reports



Overshooting Cumulus: CIT Signature





Aviation Safetyand Security Program
2005 Technical Accomplishment

NASA ASAP Turbulence Interest Fields and Simulations

POCs: John Murray[1], Dave Johnson[2], Robert Sharman[2] , Wayne Feltz[3]

Relevant Milestone: To produce turbulence interest fields useful for current and next generation satellite diagnoses of turbulence. The interest fields are developed using the output from very high resolution numerical simulations of turbulence encounters which are used as input to UW-CIMSS satellite simulations. In particular, an ATReC turbulence encounter above deep convection was analyzed in detail.

Shown: The ability to reproduce turbulence encounters using numerical simulations.

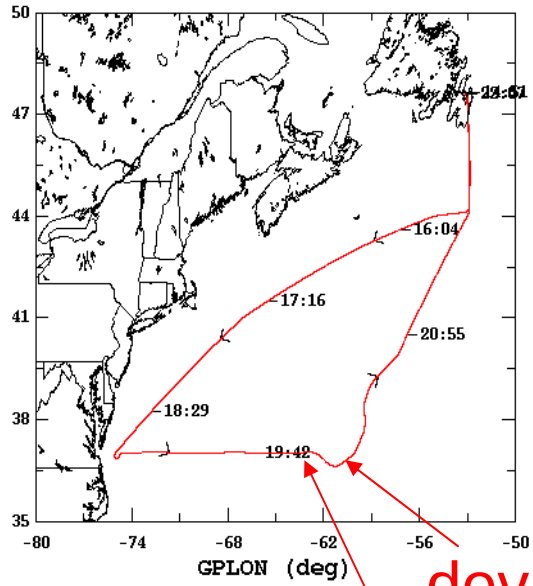
Accomplishment/Relation to Milestone: Successfully reproduced an ATReC turbulence encounter.

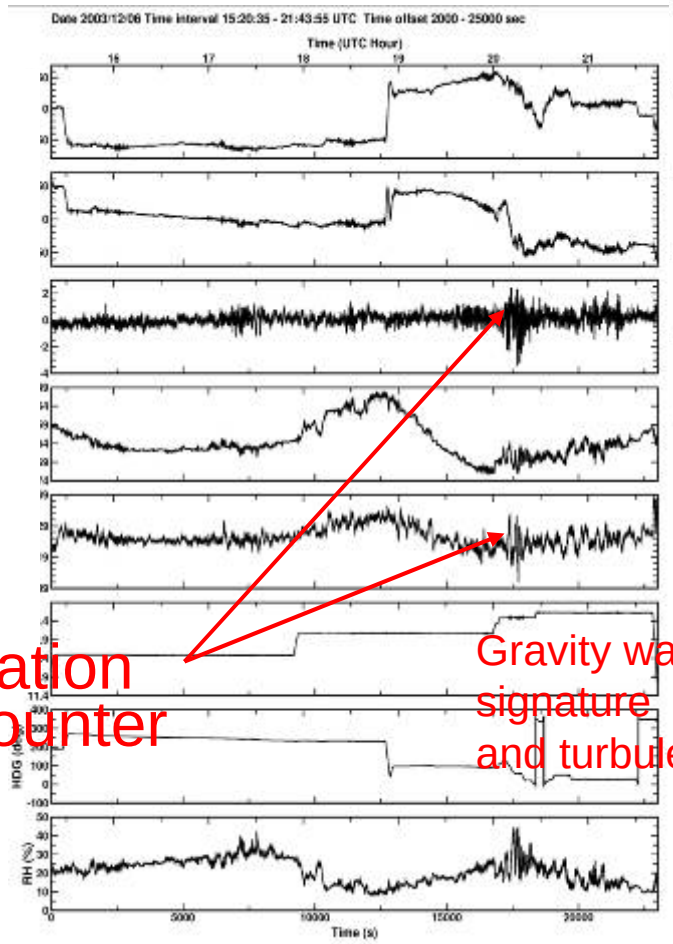
Benefits: The recreation of the fully three-dimensional plus time evolution of observed turbulence events will allow for the development of satellite-based turbulence diagnostics. This in turn will allow satellites to be used to locate turbulent regions especially over oceans and data sparse areas. The diagnostics will eventually become part of a real-time global turbulence nowcast product.

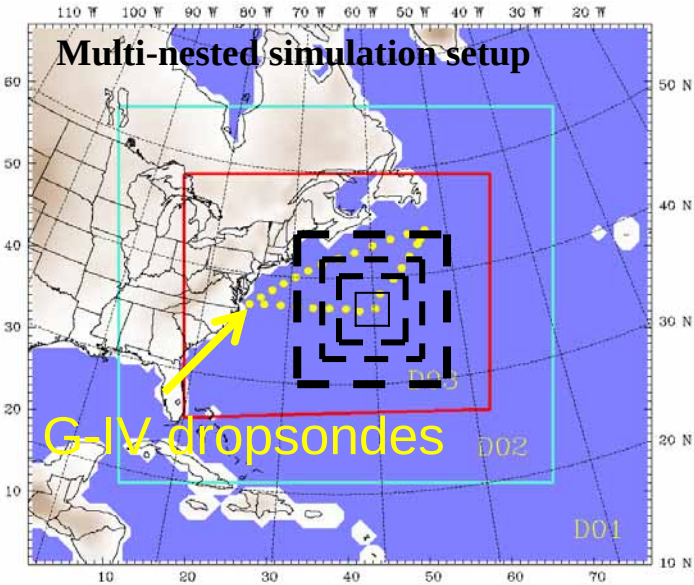
Plans: Continue development satellite-based turbulence detection algorithms and begin integration of selected discriminators into operational turbulence nowcast and forecast products.

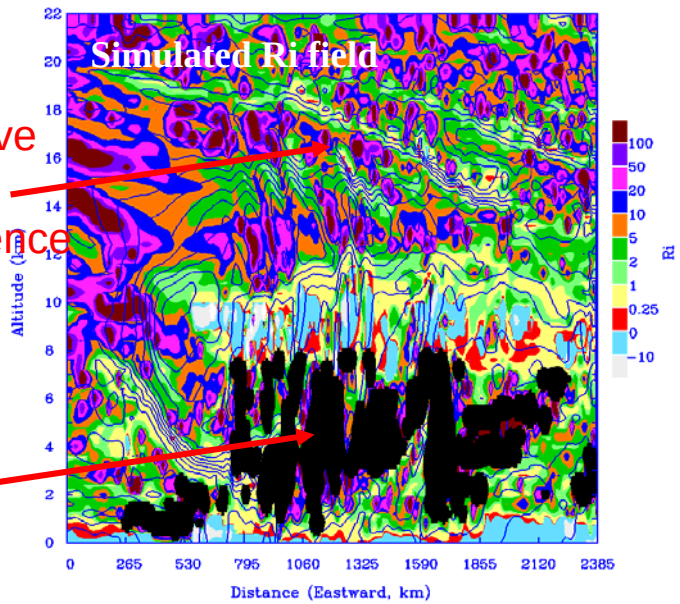
[1] *NASA Langley Research Center*
[2] *National Center for Atmospheric Research*
[3] *UW-CIMSS*

Example of simulation of turbulence encounter in the stratosphere during ATReC 6 Dec 2003









deviation

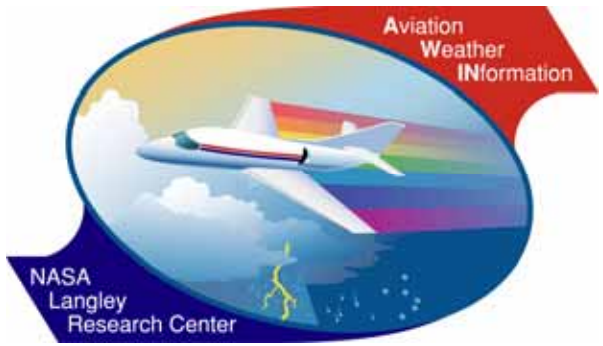
Severe encounter at 2006Z

Gravity wave signature and turbulence

clouds

Severe turbulence encounter caused NOAA G-IV aircraft to deviate from flight plan

ASAP Oceanic Winds Achievements



Aviation Safety and Security Program
2004 Technical Accomplishment

THORPEX Oceanic Flight-Level Wind Validation

POCs: Chris Velden and Wayne Feltz (SSEC/CIMSS* University of Wisconsin – Madison)
John Murray (NASA Langley Research Center)

Relevant Milestone: To simulate the density and coherency of hyperspectral resolution atmospheric motion vectors (AMV) using MM5 numerical weather prediction model output from the 2003 Pacific THORPEX experiment in Hawaii.

Shown: The ability to produce coherent oceanic AMV from derived water vapor fields (dewpoint, relative humidity, and mixing ratio fields) using mesoscale numerical weather prediction models.

Accomplishment/Relation to Milestone: Successfully derived oceanic AMV and performed preliminary validation of data using the MM5 control run for the 2003 Pacific THORPEX experiment.

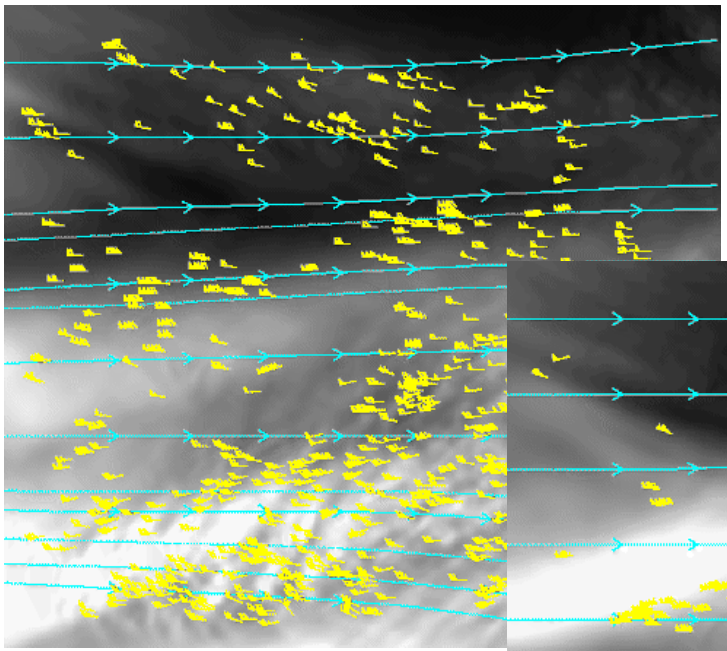
Benefits: Simulates the density and accuracy of AMV that can be expected from future hyperspectral resolution sensors such as the GIFTS engineering demonstration unit and, ultimately, the Hyperspectral Environmental Sounder (HES) that will deploy on the GOES-R satellite.

Plans: Continue the experiments by adding simulated radiances to the MM5 model analyses and re-deriving the wind fields.

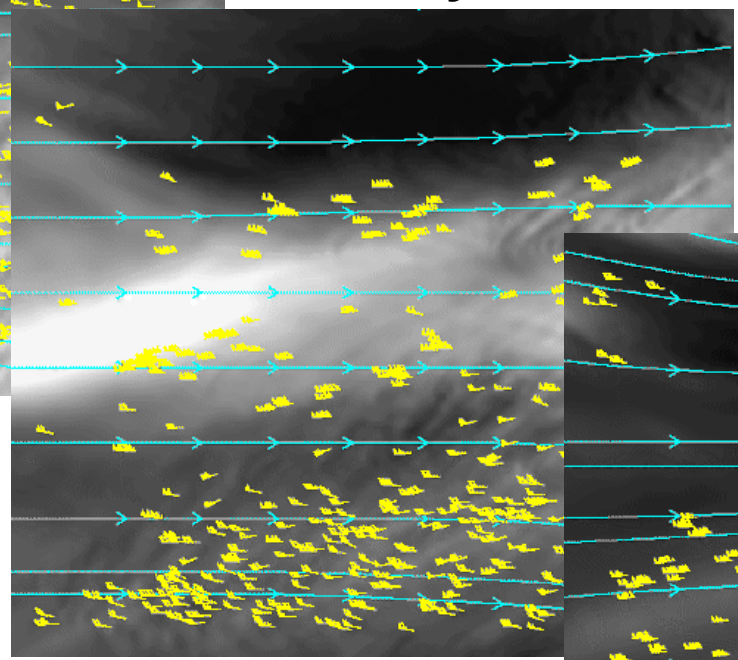
**SSEC/CIMSS: Space Science and Engineering Center/Cooperative Institute for Meteorological Satellite Studies*

Oceanic FLIGHT-LEVEL WIND VALIDATION

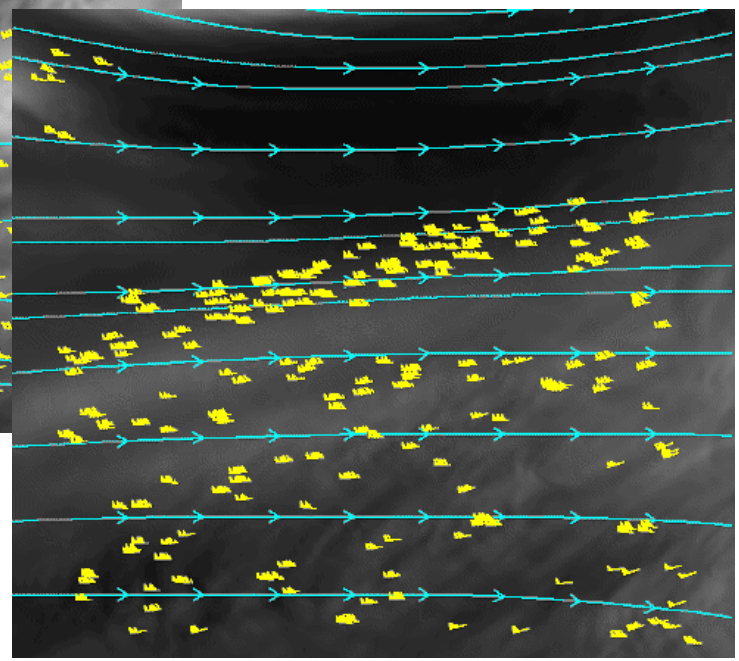
Simulated Pacific THORPEX Derived Flight-Level Winds Using Hyperspectral Resolution Relative Humidity Fields



FL 450 (150 mb)



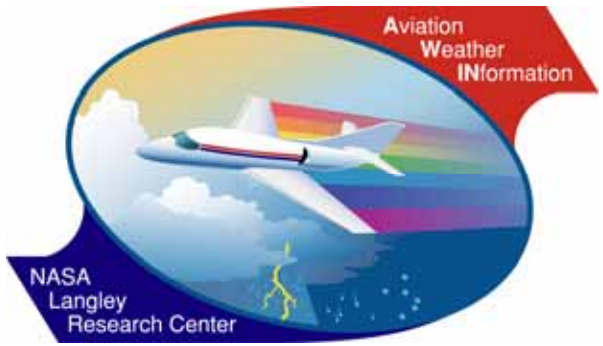
FL 340 (250 mb)



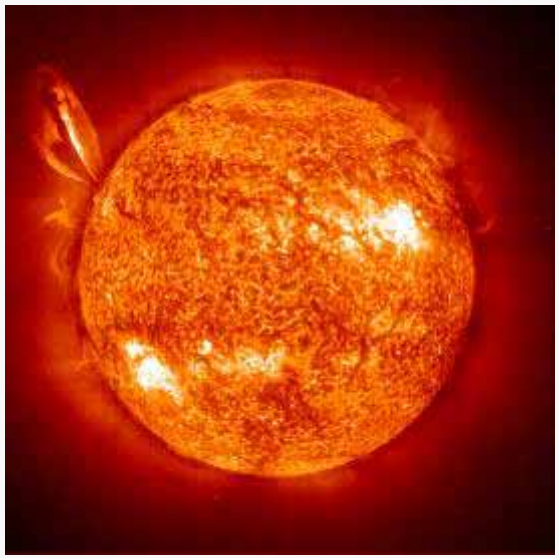
FL 320 (350 mb)

Simulated satellite derived winds are the yellow flags, and the cyan streamlines are from the MM5 u/v fields which represent "truth".

New ASAP Initiatives



Aviation Applications



SOHO EIT 30.4 nm Image, 27 July 1999

Space Weather Effects: Radiation Hazards and Nav/Com Problems

Aviation hazards from solar energetic particles, cosmic rays, and changes in the ionosphere during solar and geomagnetic events

- Solar energetic particles a significant emerging issue for commercial aviation on polar routes on an episodic basis
- Galactic cosmic rays more of a climatological problem, but vary with the solar cycle
- Changes in the ionosphere during geomagnetic storms associated with solar events can have additional implications for aviation:
  - Navigation:
    - GPS errors from TEC changes and scintillations
    - WAAS outages from large horizontal gradients
  - HF Communication:
    - Polar cap absorption events
    - Ionospheric scintillations

Partners, Approach, Milestones

- Partners:
  - NASA Aeronautics and Science Mission Directorates
  - FAA Aviation Weather Research Program
  - NOAA Space Environment Center
  - NCAR High Altitude Observatory and Research Applications Laboratory
  - NSF Center for Integrated Space Weather Modeling
  - DoD Global Assimilation of Ionospheric Measurements
- Approach:
  - ROSES Decision proposal to develop radiation exposure nowcast using space-based detectors and models
  - Model development to quantify magnetosphere-ionosphere effects during geomagnetic storms
- Milestones:
  - 3-year plan for preliminary nowcast demonstration
  - 7-year horizon for development of CISM project

Expected benefits

- Benefits to NASA Science:
  - Integration of solar particle measurements in geospace models
  - Improved understanding of magnetosphere-ionosphere-atmosphere coupling
- Benefits to commercial aviation
  - Quantification of extent of polar hazard region when solar particle events are followed by geomagnetic storms
  - Improved guidance for FAA, employee groups, at-risk passengers
  - Bounding (and ultimately correction) of GPS error limits
  - Warning of HF communication disruptions

August 2005

Aviation Applications

Next Generation Air Transportation System, Joint Planning and Development Office

Coordinated Interagency Research and Development

Interagency JPDO Weather IPT Observations Team:

•FAA, NASA, NOAA, DOD, DHS staffs JPDO Weather IPT interagency teams for observations and sensors, forecasting, integration, dissemination, mitigation and training

•JPDO Observations and Sensors Team chaired by John Murray, Applied Sciences Deputy Aviation Manager and LaRC ASAP Manager

•Plans and Coordinates Observing System requirement out to 2025 with FAA NOAA OS&TP, USGEO, OFCM and the aviation industry

Partners, Approach, Milestones

•Partners: NASA Aeronautics Research Mission Directorate, NASA Science Mission Directorate, Interagency JPDO, FAA Aviation Weather Research Program, National Weather Services Aviation Services Branch, NOAA Forecast Systems Laboratory, NCAR, UW CIMSS, MIT/LL, UAH, THORPEX, and Meteorological Services Canada

•Approach: JPDO Weather IPT coordinates all inter-agency activities for weather requirements for the Next Generation Air Transportation System

•Milestones:

- Congress has mandated $17M FAA budget allocation for JPDO, other agency contributions TBD.
- National Aviation Weather Strategy submitted to congress in Dec 2004
- JPDO WxIPT WBS completed July 2005

Expected benefits

•Benefit to Aviation: Next Generation Air Transportation System will treble capacity by 2025 through extensive redesign and automation:

•Benefit to partners: Optimal utilization of agency capabilities

•Benefit to NASA Applied science: Ensures maximum relevance and impact of NASA Satellite Technologies and Data for Aviation

•Benefits to NASA Aeronautics Research Mission Directorate:

- •Ensures maximum relevance and impact of NASA Aeronautics Technologies and related research.
- •Provides framework for further development of NASA aeronautics programs and policies

August 2005